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A Comprehensive Review On The Utilization Of Rice Straw For Sustainable Development And Future Potential

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Abstract
Rice straw is one of the natural residues of rice crop or paddy material and is an organic material. Globally, rice or paddy straw is the third largest agricultural residue after sugarcane bagasse and maize straw. Approximately 80% rice is produced by Southeast Asian countries in the world. So, every year, large quantity of paddy or rice straw produced as a by-product. Open-field burning is practiced in most of countries as well as in India, because Farmers needs immediate vacant fields for sowing of next crop and no other alternatives of rice straw. Rice straw an organic material is available in bulk quantities to most of the farmers. At crop maturity, about 40 % of the nitrogen (N), 80 to 85 % of the potassium (K), 30 to 35 % of the phosphorus (P), and 40 to 50 % of the sulphur (S) remains in rice plant parts. Generally, rice straw burned in situ or removed form field, spread or piled in field, or incorporated in the soil. The open field burning of residue contributes to harmful greenhouse gases such as NO_2, SO_2, N_2O, CH_4, carbon monoxide, particulate matter and hydrocarbon in atmosphere. The crucial purpose of this paper is to offer environment friendly alternatives to rice straw instead of open field burning such as combustion material, power generation, mushroom cultivation, bedding material for cattle, nutrition in the soil, pellet making, bio-ethanol, bio-gas, bio-char, cardboard and composite board, acoustic material, packaging materials, 3D objects, cement bricks, production of bio-composite and handmade paper.

Keywords: *Rice Straw, Burning, Pollutions, Treatments, Environment Friendly.*

1 INTRODUCTION

Rice or paddy crop is generally a grass (Gramineae) and related to the genus Oryza. Rice is a staple crop for human consumption. World's half population depends upon rice crop. In 2015, Approximately 738 Million tonnes rice produced in worldwide (McLaughlin et al., 2016). There are many varieties of rice that cultivated worldwide; mainly two species cultivated Oryza Sativa is in Asia and O. glaberrima in West Africa. Further the varieties of O.Sativa are classified in two groups (a) indica that includes all the varieties of tropical ecotype and (b) Japonica that includes temperate ecotype (Domínguez-Escribá & Porcar, 2010). Rice is the major cereal crop In India and is cultivated in nearly 43.95 million hectares area that produced 106 MT of rice.

It covers the largest area under a single crop. From this rice crop cultivation approximately 160 Mt rice straws produced. In production of one tonne rough rice, 1.35 tonnes of rice straw produced and nearly one billion tonnes every year. Generally The ratio of rice to rice straw is 1:1.5 noted by many researchers (Shukla et al., 2022) (R. B. Singh et al., n.d.). Punjab an Indian state also is known as the country's leading granary contributing nearly more than 1/3rd of wheat and ¼th share of rice to the central pool (P. Kumar et al., 2015). In year 2013-14, approximately 11.27 million tonnes of rice produced by Punjab, which is 10.6 % of India's overall production (Shukla et al., 2022).

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2 Issues in paddy straw management: India as well as worldwide:

The main producers of rice are located in Southern and South-Eastern Asia: China, Indonesia, India, Vietnam and Bangladesh. That's why the main focus of researchers on this area for better management as well as solution of rice straw (Abeysekara & Rathnayake, 2024). As we know after wheat rice is 2nd largest cereal crop that produced approximately 580 million tonnes rice straw, a useful biomass is

produced every year (D. Yadav & Wati, 2019). Most of farmers from Punjab and Haryana states trail mechanized farming because of shortage of labor and they also need to prepare their agriculture area quickly for the cultivation of next crop (Verma, 2014). So, handling of residue of paddy (rice straw) has produced from a much local regions are a vast problem.

3 Losses due to traditional handling of rice straw for environment and soil fertility:

As we already discussed that farmer need to prepare their fields quickly for the cultivation of next crop, so due to shortage of labor and time most of farmer burn the rice straw in their field. Open field burning of paddy straw generally leads to air, water and land pollution i.e. a massive problem to the environment (Verma, 2014) (Bhattacharyya et al., 2021). Open field burning of paddy crop residue produces very harmful gases like CH_4, NO_2, SO_2, N_2O and carbon monoxide as well as the hydrocarbon and particulate matter in the atmosphere (Romasanta et al., 2017).Punjab Agriculture University, Ludhiana (PAU) projected that rice crop residue comprises carbon content about 6 million tonnes; due to open field burning it produced nearly 22 million tonnes of Carbon dioxide (CO_2) within a 15-20 days of time period (P. Kumar et al., 2015). Although the Government of Punjab state banned the stubble burning, but farmers usually flout the ban to save money (from mechanized stubble management). The Supreme Court of India already gives a strict statement regarding burning of crop residue in Punjab, Haryana, Delhi and Uttar Pradesh Northern Indian states of India (Kaur, 2017).

4 Alternatives of Rice straw Management

The two main classifications of rice straw management are: In-situ options and off-situ options. The in-situ options for rice stubble are further classified as incorporation of crop residue (rice straw) in the field and direct open field burning of rice straw in the field.

Similarly, off-situ options are further classified in three main groups: Energy Production Agriculture/ Dairy, and manufacturing. The various environment friendly alternatives are discussed below one by one in details:

4.1 In-situ options for rice straw management

The two main situ options for rice stubble management are: preparation of manure from the rice crop residue in the field and open field burning of rice straw residue in the field. These are further explained below:

4.1.1 Incorporation of rice crop residue in the field

Many researchers investigated that productive quality of soil decrease with burning of crop residue in the field. The decomposing process of crop residue depends upon oxygen availability, carbon nitrogen ratio, and moisture content in rice straw, PH value and temperature. Researchers are further working for preparation of compost from rice straw residue to improve the soil's quality. Use of such type of compost increase the crop yield problem by 4-9 % .The method for rice straw incorporation in the soil is shown in Fig. 1(Verma, 2014) (M. Yadav et al., 2014).

Figure 1. Rice straw incorporation in soil (Verma, 2014)

For the rapidly breakdown of rice straw, addition of special type fungus showed result in 80-90 days. Moreover it investigated that, if rice crop residue treated with P.Sajorcaju, T. Harizianum and cow dung before incorporation adds the nutrients content in soil (A. Kumar et al., 2019) (Vagg, n.d.).

4.1.2 Open field burning of rice crop residue in the field

The storage of excess rice straw is a serious problem worldwide. Most of farmers burn the rice straw in their field so that, they prepare fields in short time for next crop cultivation (Shukla et al. 2022) (M. Yadav et al. 2014). open field burning of rice crop residue produced huge quantity of carbon dioxide gas which is very harmful for our environment and is directly related to greenhouse effect (Zayed & Abdel-Motaal, 2005). Rice crop residue also contains lots of nutrients like N, Ca, Mg, P_2O_5 and many more that are lost during the open field burning. Fig No. 2 shows the open field burning of rice straw (McLaughlin et al., 2016) (Kadam et al., 2000) .

Figure 2. Open field burning of rice straw (Arunrat et al., 2023)

4.2 Off-situ options for rice straw management

Various types of off-situ options are exercised only after the removal of rice crop residue (rice straw) from the field. Rice straw has been removed from the field by using various agriculture implements. Such type of implements converts rice stubble into roller or rectangular shaped bundles. Various off-situ options are explained below:

4.2.1 Rice straw in cultivation of mushroom:

A variety of waste materials, including rice bran, wheat bran, rice straw, sawdust, banana leaves, and sugarcane bagasse, were utilized to identify the perfect spawn substrate (Tripathy, n.d.). Usually these three-leading variety of mushroom are cultivated in India are V. dysplasia, V. esculenta, and V. volvacea. In India mushroom was first time cultivated in 1943 by Thomas et al. at Coimbatore. FAO (Food and Agriculture Organisation) reports that India had produced approximately 29992 tonnes of mushroom in 2016 and took 5th place for production of mushroom (K. Singh et al., 2018). The paddy straw mushroom, which accounts for over sixty-six percent of cultivation in Odisha, contributes a mere one percent globally and seven percent throughout India. (Rath & Mishra, 2023). The mushroom cultivation with rice straw is shown in Fig. No. 3 given below.

Figure 3. Mushroom Cultivation from rice straw (Gurudevan Thiribhuvanamala, 2012)

First off, all rice straw cuts into small size and soaked with formalin solution. Spawning process has been takes place in rice straw contains nearly 75% moisture in different layers. For aeration purpose polythene cover is removed daily just for 30 minutes. This cover has been completely removed after 10-12 days. Production cycle of such type of mushroom is only for few days (K. Singh et al., 2018).

4.2.2 Rice straw as bedding materials for cattle:

Rice crop residue delivers comfortable, dry, non-slippery, clean and hygienic environment that reduce chances of various types of diseases and injury. Punjab agricultural university, Ludhiana already recommended the rice crop residue in winter season. The milk production and efficiency of dairy farms is more as they adopted such types of advisory (P. Kumar et al., 2015) (R. B. Singh et al., n.d.) . Fig No. 4 shows the use of rice straw for cattle bedding material.

Figure 4. Rice straw for cattle bedding (Kupczyński et al., 2023)

4.2.3 Rice straw to enrich the nutrients for soil

The Compost can produce from the rice straw to control the environmental pollution. Rice straw contains calorific value as well as various nutrients. For efficient results rice straw is mixed with some other organic wastes for better compost production. This process reduces the C/N ratio as well as volume of wastage. Composting process directly depends upon ph. value, moisture content, degree of aeration, C/N ratio, temperature and added waste materials (Li et al., 2008) (Rashad et al., 2010).

4.2.4 Rice straw for power generation:

The growing demand of power energy can be fulfilled by using rice crop residue in production of power generation. It will also provide an extra income to the farmers and helps in to control the environment pollution. Power plant with capacity of 12 MW was set up in Vill. Ghanaur district Patiala of Punjab state as shown in Fig No. 5. Such type of more power plant may installed if large quantity of biomass available locally (Verma, 2014).

Figure 5. Power production from rice straw (Verma, 2014)

The thermal efficiency of rice crop residue is nearly 60-75 % and further increases by upgrading the technologies. For better combustion of rice crop residue it is altered in shredded form.The preliminary treatment of rice straw has demonstrated an enhancement of its chemical and physical qualities, hence reducing the expenses related to handling, transport, and storage (Kargbo et al., 2010).

4.2.5 Rice crop residue as combustion material:

Various methods are exercised to prepare the rice crop residue for combustion purpose. Mostly two methods are used either alone combustion or it can mix with some other biomass for combustion. Researcher investigated that if moisture content in rice straw is more than 25 % then fermentation of rice straw starts (Liu et al., 2011). Rice straw inserted in combustion chamber for burning purpose. Before

it, rice straw should be properly dried so that efficiency of plant increases. Rice straw burns in combustion chamber either in baled form or in shredded form. Moreover the byproducts of rice straw after burn is also used in manufacturing roads, cement, bricks and many more (Verma, 2014). Fig No. 4 shown the use of rice straw for cattle bedding material. Fig No. 6 shows the use of rice straw as a combustion material.

Figure 6. Rice straw as Combustion material (Verma, 2014)

4.2.6 Rice straw for pallet making:

In current scenario, Researchers works on pallet making form the various crop residue or biomass that are easily available in large quantity at minimum price. Generally, rice straw, soybean rod, peanut shell, cotton bar any many more solid waste should be used as raw material in Pellet process. The Pallet prepared from the rice straw is shown in Fig No. 7 given below.

Figure 7. Pallet making from rice straw (Verma, 2014)

In pallet making process first of all these raw materials are crushed in small size. After that, crushed raw material is pressed in pressing machine at suitable pressure. The pressing pressure depends upon the used raw materials. Now the raw materials converted into small size solid pallet with high density. The most important advantage of pallet is that its transportation is very easy. Generally pallet is used in industrial furnace, life stoves and biomass power plant (Dinh et al., 2022).

4.2.7 Rice straw for Biogas production:

Biogas is always produced in special dome shaped designed biogas plant. Generally, a dimension of such biogas plants is of 4m height and 2.5 m width and is constructed from the cement and bricks at specific ratio. The Bio-gas production unit is shown in Fig No. 8. Earlier such type of constructed biogas plant was working only cow dung. Now, alternate layers of rice straw and cow dung placed with half meter of thickness. Finally, the plant is filled with water. The production of biogas starts just after one week due to fermentation process. The straw will serve as a substrate as the enzymatic and microbial activity accelerates the gas generation process (Li et al., 2008)
(Vagg, n.d.) (Zayed & Abdel-Motaal, 2005).

Figure 8. Bio-gas production from rice straw (Vagg, n.d.)

4.2.8 Rice straw as packing material:

Better compaction resistance and Good resilience property makes it very suitable for manufacturing of packing materials. These types of prepared material also reduce the use of petroleum based products already in used from long time (Verma, 2014) (R. B. Singh et al., n.d.).

4.2.9 Rice straw for paper production:

The large quantity of hollo-cellulose and high fibrous lignocellulose property of rice straw makes if suitable in manufacturing of paper (Kadam et al., 2000). For pulp production different chemicals are used in industry. A good quality of pulp is produced if liquid to straw ration 10, 85% concentration of acetic acid, 1% sulfuric acid concentration at 90^{o}C is taken (Suseno et al., 2019).

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